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(54) Automatic repeat request with adaptive latency

(57) In a transmission environment, such as a wireless environment, the communication channel 23 may be subject to noise bursts 27, 28. When the transmitter 2 sends a frame 24(8) to the receiver, it may collide with a noise burst 28. The receiver 4 is adapted to send a retransmission request, 25(8) Original, when it receives corrupted data from transmitter 2. The duration of the noise may be sufficient to also interfere with the request, 25(8) Original. The receiver includes channel monitoring means to detect noise and to delay the sending of the retransmission request, 25(8) Delayed, based on the level of the noise.

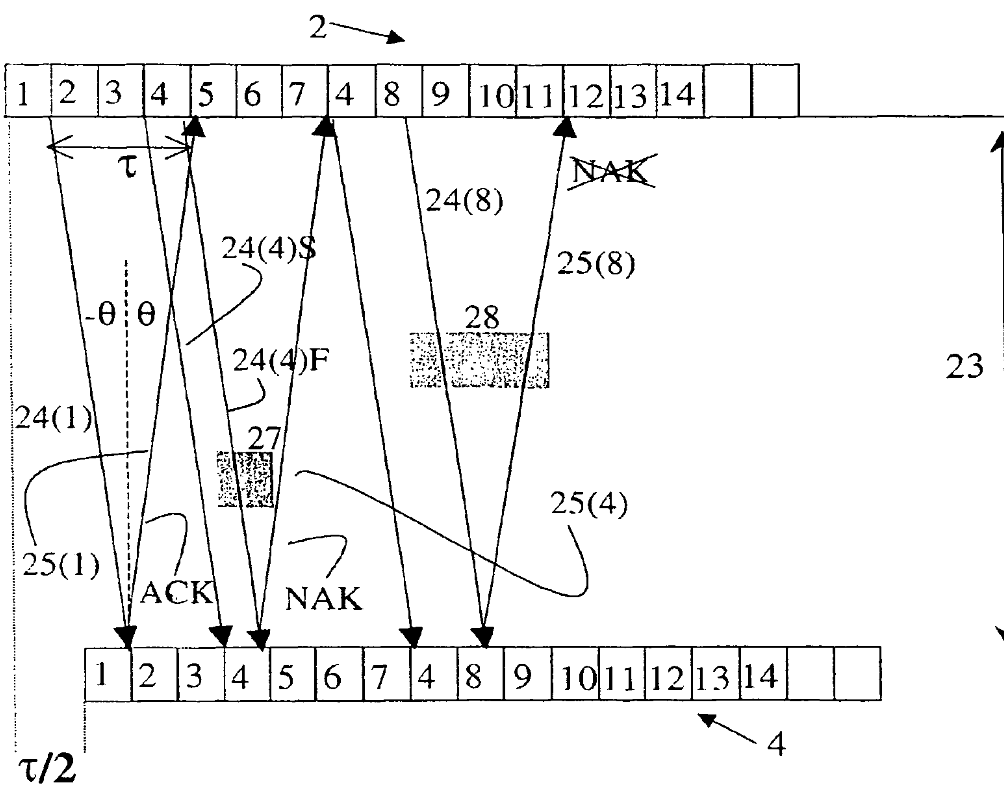

FIGURE 2

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Description

Field of the invention

[0001] This invention relates to error correction in a transmission environment subject to noise bursts of varying durations, using an Automatic Repeat Request (ARQ) technique in which a receiving unit requests a sending unit to resend data which has been corrupted by a noise burst.

Background of the invention

[0002] Communication channels, such as wireless channels and other channels carrying digital communication, are subject to noise. The noise can be difficult to characterize, as it depends on the environment of the communication system. Noise bursts can corrupt large parts of a message as it may disturb a channel for a relatively long time. The noise bursts can be widely distributed geographically and can also vary in duration and noise level.

[0003] Typically messages are encapsulated in a frame structure and transmitted in sequential frames over a down channel from the transmitting unit to a receiving unit. In some transmission systems, in order for the transmitting unit to have assurance that the message is received correctly, the receiving unit transmits some form of acknowledgment signal to the transmitting unit over an up channel.

[0004] It is known to use automatic repeat requests (ARQ), possibly combined with forward error correction, to cause uncorrectable frames to be retransmitted until they are received correctly, or until a maximum permitted number of repeat requests is reached.

[0005] The article "A Class of Adaptive Hybrid ARQ Schemes for Wireless Links" Sunghyun Choi, IEEE Transactions on Vehicular Technology, Vol. 50, No. 3, May 2001, discusses three correction schemes including a system using an adaptive hybrid forward error correction (FEC) and ARQ using Reed Solomon code. The paper describes the selective-repeat ARQ in which the sender transmits frames without waiting for an acknowledgement (ACK) or negative acknowledgement (NAK) of frames already transmitted. this version of ARQ has better throughput than the "stop-and-wait" or the "go-back-N" versions. If the receiver is unable to correct errors using the FEC, it sends a NAK signal to the transmitter initiating re-transmission of the corrupted frame or code segment depending on the specific ARQ implementation. The NAK frame includes four bytes, the first two bytes being used to identify the frame number, the third identifying (a) whether the response is ACK or NAK and (b) adapted code rate, and the last being a checksum. In addition, if neither ACK/NAK is not received by the transmitter within a timeout interval, the frame is retransmitted. The timeout is based on the round trip delay.

[0006] The current forms of ARQ can be effective against some forms of noise, but particularly where the noise is of long duration, the "fixed-delay" ARQ may suffer interference when the noise is still present in the channel. If the number of ARQ repeats does not exceed the maximum permitted number, it may still be possible for a repeat ARQ to be sent to request the retransmission. However, for each retransmission the latency is increased with the round trip delay and the throughput of the system can drop significantly. This may be unacceptable where latency and throughput are important. The automatic retransmission of packets when an ACK is not received can reduce the effective bandwidth of the channel by causing the unnecessary retransmission of frames which have been correctly received and only the ACK signal has been corrupted.

Summary of the invention

[0007] It is an object of the invention to provide a method of reducing the effect of interference with a response signal sent to notify a transmitting unit that its transmission has been corrupted by a noise burst, the method reducing the probability that the response signal will be corrupted by the noise burst.

[0008] According to a first aspect of the invention there is provided a method of reducing interference with a response signal sent from a reception unit to a transmission unit in a transmission environment subject to noise bursts when the reception unit has received data from the transmission unit corrupted by bursts noise in the transmission environment, the method being characterized by the following steps:

monitoring a variable condition of the channel, and

delaying the response signal for a delay period based on the monitored condition of the channel.

[0009] The invention further provides a response generation arrangement for reducing the effect of noise bursts on a response signal transmitted in an environment subject to noise, the arrangement including:

noise evaluation means to directly or indirectly evaluate a characteristic of noise on a channel,

delay means to delay transmission of the response signal based on the characteristic of the noise.

[0010] The channel condition may be monitored directly by directly monitoring the presence of noise. Alternatively, or in addition, the channel condition may be monitored indirectly by monitoring the uncorrupted reception of a data frame. Monitoring may include one or more of the following:

testing to see if the energy of the received signal is

abnormally high during a certain time interval;

checking for known patterns of impulse noise or noise bursts;

checking for consecutive erroneous packets.

[0011] The noise patterns may be determined by measuring and characterizing the medium (wireless, cable, copper pair, etc.).

[0012] The invention still further provides a system for transmitting framed data over a channel from a transmitting unit including first transmission and reception means to a reception unit including second transmission and reception means, the reception unit including the aforegoing response generation unit, and the transmission unit including means responsive to a delayed response from the reception unit indicating reception of at least one corrupted frame of data to retransmit the corrupted frame or frames.

Brief description of the drawings

[0013]

Figure 1 shows a block diagram of a communication system with a noise source shown illustratively as a noise generator interfering with a communication channel;

Figure 2 shows is a space/time diagram illustrating the operation of an ARQ system between a transmitting unit and a receiving unit;

Figure 3 shows is a block diagram of an arrangement in a receiver implementing an embodiment of the invention;

Figure 4 shows is a space/time diagram illustrating the operation of the invention

Figure 5 shows a detail of the effect of a noise burst on the receiver and transmitting units.

Figure 6 shows a functional block diagram of a receiver embodying the invention

Detailed description of the embodiments

[0014] Figure 1 represents a data source 101 connected to a transmitting unit 102 transmitting data over a channel 103 to a receiving unit 104 connected to a destination 105. The channel 103 is subject to noise and this is represented by a noise source 106 which produces noise which may corrupt the transmission of data between the transmitting unit 102 and the receiving unit 104.

[0015] The space/time diagram in Figure 2 represents the transfer of signals from the transmitting unit to the receiving unit across an intervening distance 23. The horizontal direction represents time and the vertical distance represents the displacement in space. In this example, we will assume that the transmission is wireless transmission. As shown in Figure 2, the transmission of framel space between the transmitter 102 and the receiver 104 is represented by the arrow 24(1). This arrow is a purely figurative representation of the space/time location of the frame being transmitted. Assuming that the distance between the transmitter and the receiver is constant and ignoring variables such as multipath fading, the transmission time will remain constant. This is represented by the angle of the arrow 24(n) remaining constant for each down-link transmission. The uplink transmissions also travel at the same speed, so the arrows 25(n) representing the uplink transmissions have the same angle in the reverse direction so they appear at an equal and opposite angle to the vertical with reference to the down-link arrows. The transmission medium may be air or cable.

[0016] Also shown in Figure 2 are two noise bursts 27 and 28 which appear unpredictably between the transmitter and the receiver, and are of varying durations.

[0017] In Figure 2, the frame numbered 1 from the transmitter 102 arrives uncorrupted along arrow 24(1) at the receiver shifted in time by $\tau/2$, half the round trip delay τ, ie, $\tau/2$ is the time taken by the signal to travel the distance between the transmitter 102 and the receiver 104. The receiver 104 transmits an acknowledgment signal to the transmitter along arrow 25(1). This ACK signal arrives after a half round trip delay at a time corresponding with the frame 4 in this example although on a different frequency channel, assuming the channels are not time shared. In the meantime, the transmitter has continued to send data frames. Frames 2 and 3 arrive safely at the receiver. The ACK responses for the reception of these signals is omitted from the drawing for the sake of clarity, but frame 4, transmitted on arrow 24(4), collides with the noise burst 27 during transmission and is corrupted. It should be noted that the frame 4 takes a finite time to pass across any point in the channel. This finite time corresponds to the frame duration and is represented by the arrows 24(4)S, the start of transmission of frame 4 and 24(4)F, the finish of transmission of frame 4. The receiver recognizes the frame 4 is corrupted by the noise burst 27 and sends an NAK signal along arrow 25(4) to the transmitter.

[0018] Because the noise burst is narrow (of short duration), the NAK sent on arrow 25(4) arrives at the transmitter 102 without interference during frame 7. Thus the transmitter 102 is able to receive and understand the NAK requesting re-transmission of the frame 4 while it is sending frame 7. The transmitter responds by resending frame 4 after it has sent frame 7. Frame 4 may be retransmitted immediately after frame 7 or after a later frame depending on the arrival time of the NAK sent on arrow 25(4).

[0019] In the example in Figure 2, the transmitter 102 next sends frame 8 on arrow 24(8). This collides with noise burst 28 and is corrupted before arriving at the receiver 104. In response to the reception of the corrupted frame 8, the receiver 104 sends an NAK on arrow 25 (8). In this case, the noise burst 28 is of longer duration than noise burst 27 and is still affecting reception at transmitter 102 when the NAK arrow 25(8) reaches transmitter 2. Thus this NAK is corrupted, and the transmitter 102 is not able to respond to it.

[0020] The receiver 104 anticipates the reception of retransmitted frame 8 after the round trip delay. If this is not received within the expected time window, receiver 104 will again send the NAK requesting re-transmission of the frame 8, until the number of permitted repeats has been used or the frame is received. Each time the NAK is transmitted there is a round trip delay to be accounted for and if the faulty frame is not received within a time window determined by the system specification, the frame will be lost. Even if one of the following NAKs is successfully received by the transmitter and frame 8 is re-transmitted, the latency of the system is increased by the number of retries times the round trip delay plus any internal delays, as the received message cannot be reassembled until the missing frame is received.

[0021] Looking at the noise burst 28, it is seen that the burst has a spread in time and may also have a spread in space, its width representing its time spread, and its height representing the spread in space. Thus, any down-link signal (the arrows sloping down to the right) which falls inside the lower left corner and the upper right corner will suffer interference. Similarly, any uplink signal which falls between the upper left corner and the lower right corner will suffer interference during transit to the transmitter. In some cases, the spread in space may be negligible compared with the spread in time.

[0022] The invention proposes a process of monitoring the channel to determine the distribution of the noise in time and delaying the transmission of the ARQ until after the noise burst has finished or fallen to a level where it will not substantially corrupt the data.

[0023] Figure 3 illustrates the functional blocks for achieving this result.

[0024] In Figure 3, the packet or frame is received at 31. The receiver decodes the data at stage 32 and finds uncorrectable errors. The receiver continues to monitor the received data until it recognizes that the error source has ceased at stage 33. This may be done, eg, by recognizing when an uncorrupted packet is received. The receiver can thus identify the corrupted packet or packets. The receiver delays the transmission of the NAK until the noise burst ceases or falls below a predetermined threshold, as is shown at 34. Once the receiver recognizes that the noise burst has ended, it sends an NAK requesting the retransmission of the missing packet or packets, as shown at step 35.

[0025] This is represented in the space-time chart of Figure 4, where the action in relation to the earlier packets is the same as in Figure 4. However, the response to the corruption of packet 8 by the noise burst 28, which has a duration τn, is different. Receiver 104 recognizes that the packet received after retransmitted packet 4 is corrupted, and that the next uncorrupted packet is packet 11, because both packets 9 and 10 are also corrupted by the noise burst 28, as well as packet 8. As a result, receiver 104 delays sending the NAK request for the retransmission of packet 8 until it recognizes that the noise burst has ended. Thus the NAK 25(8) is not sent until after the clear reception of packet 11. In one embodiment, the NAK may be modified to request the retransmission of the three corrupted packets, 8, 9, and 10. Alternatively, single NAKs may be sent for each of the three corrupted packets.

[0026] Figure 5 shows in a more detailed manner a method of representing interference in a wireless environment. The noise burst spreads from the noise source 50 in both directions, towards the receiver 104 parallel to the arrows 25(n), and towards the transmitter 102, parallel to the arrows 24(n), causing interference to the data signals which arrive at the transceivers at either end at the same time as the noise burst. Thus, as shown in Figure 5, any signal from the receiver end 104 arriving at the transmitter end 102 during the packet periods for packets 10 and 11 will suffer interference from the noise burst 50. Similarly, at least some of the data arriving at the receiver end during the period 8, all of the data arriving during period 9, and some of the data during period 10 will suffer interference from the noise burst 50.

[0027] There is thus an alternative method of determining when the noise burst has ceased. This may be done by monitoring for the noise directly, rather than by detecting the clear reception of a packet. However, if the noise ceases during a packet, the initial part of the data of that packet will be corrupted and the packet may need to be retransmitted.

[0028] It should also be noted that the noise burst may not produce substantial interference with the "non-parallel" data which transects it. Thus the data from packet 11 transmitted by transmitter 102 is not interfered with by the arrival of the noise burst 50 at transmitter 102. However, the packet 24(8) is interfered with by the "parallel" noise burst arriving simultaneously at the receiver 104.

[0029] Figure 6 shows a functional block diagram of the receiver functions embodying the invention. The channel input is applied to a demodulator 61 and the output of the demodulator is applied to a decoder 62. Where the decoder is able to decode packets, these are forwarded for further handling or processing, eg to buffer manager 63. The channel input is also applied to channel monitor 64 which controls the addition of an adaptable delay 65 before the transmission of the ACK/NAK response 66. The adaptable delay 65 may also be controlled from the decoder if it is unable to decode a number of consecutive packets, indicating the presence of a disturbance on the channel.

[0030] The input of the demodulator is a stream of digital waveforms. The demodulator does all operations necessary to convert this stream to a stream of packets. This packet-stream is delivered to the decoder. The decoder decodes and possibly corrects the bits contained in the packet according the selected error correction scheme. The output of the decoder is an error-free packet stream on the one hand, or, where applicable, an indication of an uncorrectable packet of bits. The error-free packet-stream is the input of the buffer management block. This block aligns all packets in the correct order before they are delivered to the higher layers of the device. The channel monitor block monitors the channel in order to detect the presence of burst noise. The inputs of this block come from either the channel or the decoder, or from both. The presence/absence of noise controls the addition of an adaptable delay to the response of the received packets.

[0031] In an alternative embodiment, the transmitter monitors the channel conditions and interrupts transmission where the transmitter detects an unfavourable noise environment. This may be of particular use in an environment which is subject to noise bursts of relatively long duration compared to the frame duration. One such environment may occur during a period of high solar flare activity when wireless transmissions can be disrupted for long intervals. One advantage of such a technique is that the amount of time required for reassembly of frames into correct sequence may be reduced in some cases. This technique can be applied together with the technique of sending delayed NAK signals from the receiver. In particular, the cessation of transmission is arranged to operate if the transmitter detects that the noise burst has a duration greater than a predetermined threshold period. Thus the receiver send NAK signals for noise bursts having a duration to the predetermined threshold period, but for longer noise bursts the receiver is programmed to recognize that the transmitter has stopped transmitting. After such a prolonged outage, it would normally be necessary to reinitialize the communication. The transmitter needs to have sufficient memory to retain the frames transmitted during the noise burst at least up to the threshold period. Thus the threshold period acts as a "bookmark" so that the communication can be reestablished from the time the noise burst commenced.

[0032] It will be understood that the invention disclosed and defined herein extends to all alternative combinations of two or more of the individual features mentioned or evident from the text or drawings. All of these different combinations constitute various alternative aspects of the invention.

[0033] The foregoing describes embodiments of the present invention and modifications, obvious to those skilled in the art can be made thereto, without departing from the scope of the present invention.

Claims

1. A method of reducing interference with a response signal sent from a reception unit to a transmission unit in a transmission environment subject to noise when the reception unit has received labelled data segments from the transmission unit corrupted by noise in the transmission environment, **characterized in that** the method includes the steps of:

   directly or indirectly monitoring one or more channel conditions at the reception unit;

   delaying the response signal for a delay period based on the monitored channel conditions.

2. A method as claimed in claim 1 **characterized in that** the monitored channel condition is the presence of noise, and the response signal is a request to the transmitting unit to resend data which has been corrupted by noise imposed on the channel.

3. A method as claimed in claim 2, **characterized in that** a characteristic of the noise is monitored directly and the response signal is transmitted after the level of the noise has fallen below a predetermined level.

4. A method as claimed in any one of claims 1 to 3 **characterized in that** the reception unit includes noise evaluation means which directly monitors the level of noise on the channel, the method further being **characterized by** the steps of: evaluating the level of momentary noise on the channel, and

   delaying the response signal based on the level of momentary noise.

5. A method as claimed in any one of claims 1 to 3 **characterized in that** the reception unit received signal energy evaluation means which directly monitors the energy of the received signal during a predetermined period, the method further being **characterized by** the steps of: evaluating the energy of the received signals, and

   delaying the response signal until the energy of the received signal falls below a predetermined threshold.

6. A method as claimed in claim 4 **characterized in that** the reception unit includes noise evaluation means and response delaying means, the method further being **characterized by** the steps of using the noise evaluation means to evaluate the characteristics of momentary noise, and using the delaying means to delay the response based on the characteristics of noise.

7. A method as claimed in any one of claims 1 to 4,

characterized in that the data from the transmission unit is sent in frames or packets, and the reception unit monitors the data frames or packets to determine indirectly the channel characteristics and requests re-transmission of corrupted frames or packets based on the channel characteristics which permit uncorrupted reception of a frame or packet.

8. A response generation arrangement for reducing the effect of noise on a response signal transmitted in an environment subject to noise bursts, the arrangement including a transceiver for receiving framed data over a channel and sending a response over the channel when received data has been corrupted, **characterized in that** the arrangement includes:

   noise evaluation means to directly or indirectly evaluate the channel characteristics, and

   delay means to delay transmission of the response signal based on the channel characteristics.

9. A response generation arrangement as claimed in claim 8 **characterized in that** it includes a reception unit including a noise monitor monitoring a channel for the presence of noise having predetermined characteristics, and delay means for delaying the transmission of a response message until the characteristics of the noise are within an acceptable range.

10. A system for transmitting framed data over a channel from a transmitting unit including first transmission and reception means to a reception unit including second transmission and reception means, **characterized in that** the reception unit includes an arrangement as claimed in claim 9, and **in that** the transmission unit includes means responsive to a delayed response from the reception unit indicating reception of at least one corrupted frame of data to retransmit the corrupted frame or frames.

11. A method of controlling data transmissions over a link from a transmitter to at least one receiver in an environment subject to noise, **characterized by** the steps of monitoring the link for noise at the transmitter end, and ceasing transmission when one or more of the noise characteristics exceeds an associated predetermined threshold.

12. A method as claimed in claim 12, **characterized in that** the transmitter ceases transmission when the noise exceeds a predetermined level for a predetermined period.

13. A method as claimed in claim 12, **characterized in that** the transmitter stores transmitted data for a period equal to or greater than the predetermined period.

14. A method as claimed in any one of claims 11 to 13, wherein the receiver implements the method of any one of claims 1 to 7 for a period equal to or greater than the predetermined period.

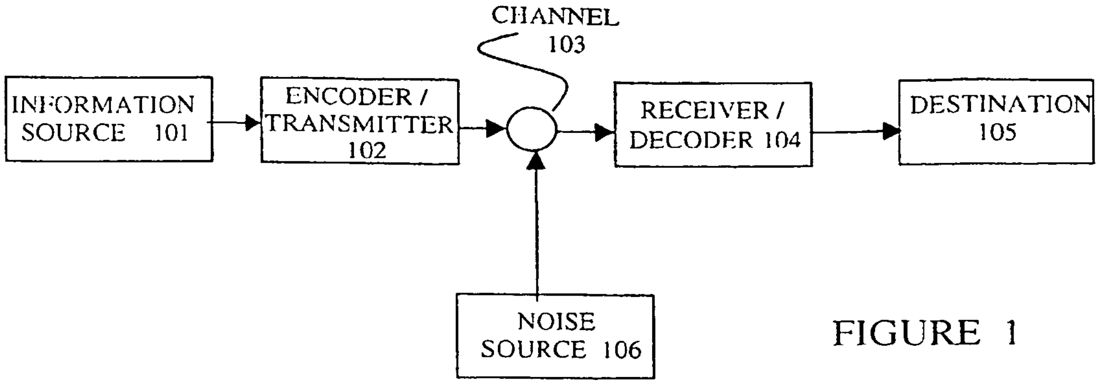


FIGURE 1

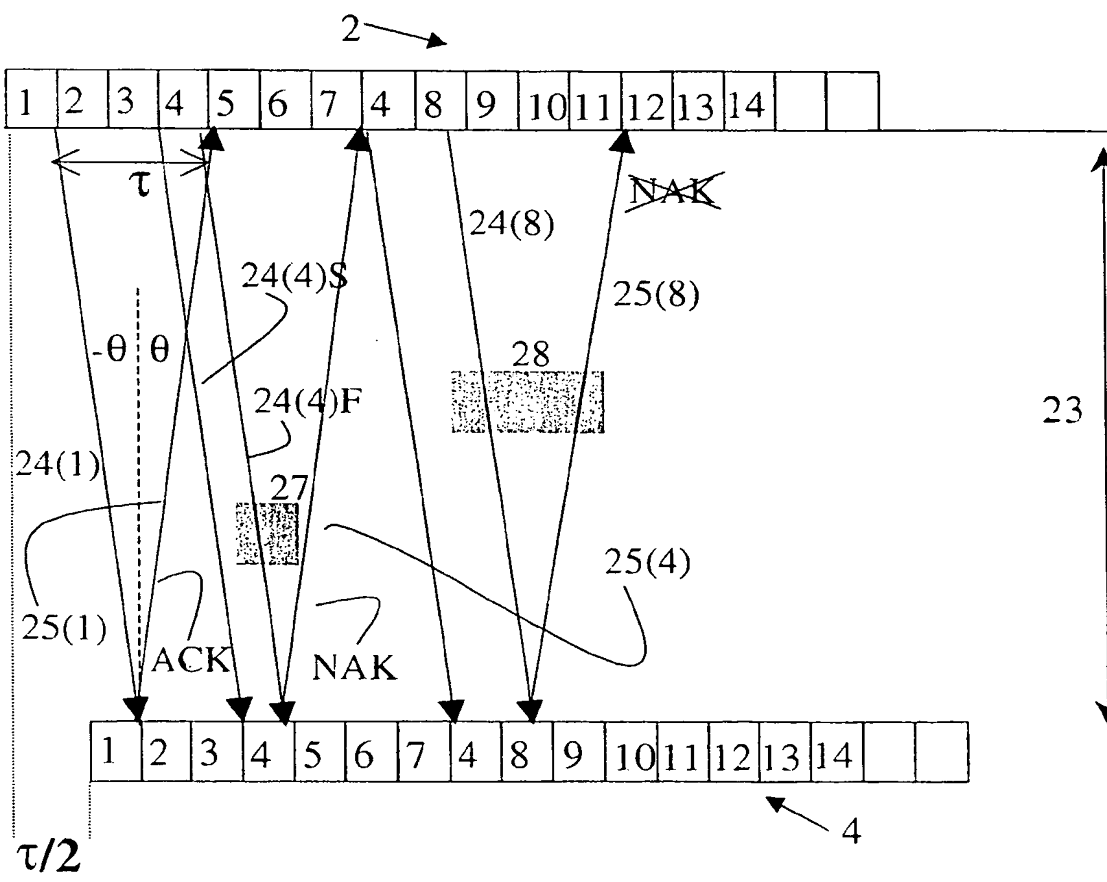
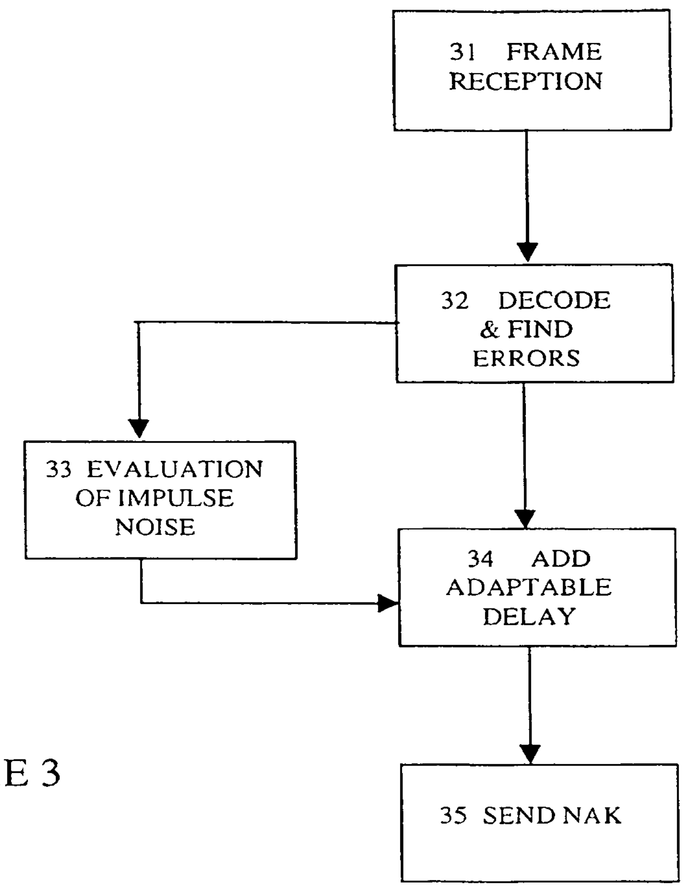


FIGURE 2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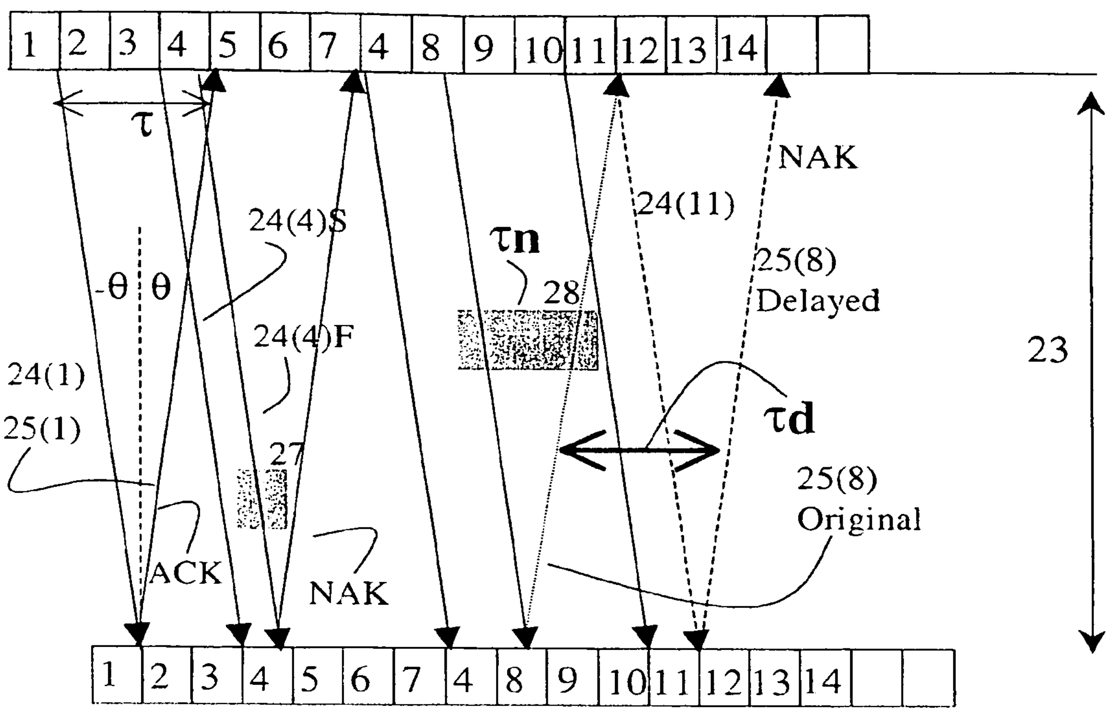
32 DECODE & FIND ERRORS
33 EVALUATION OF IMPULSE NOISE
34 ADD ADAPTABLE DELAY
35 SEND NAK

FIGURE 3


1
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3
4
5
6
7
4
8
9
10
11
12
13
14
τ
NAK
24(11)
24(4)S
τn
25(8)
Delayed
-θ
θ
28
24(4)F
23
24(1)
25(1)
τd
27
25(8)
Original
ACK
NAK
1
2
3
4
5
6
7
4
8
9
10
11
12
13
14

FIGURE 4

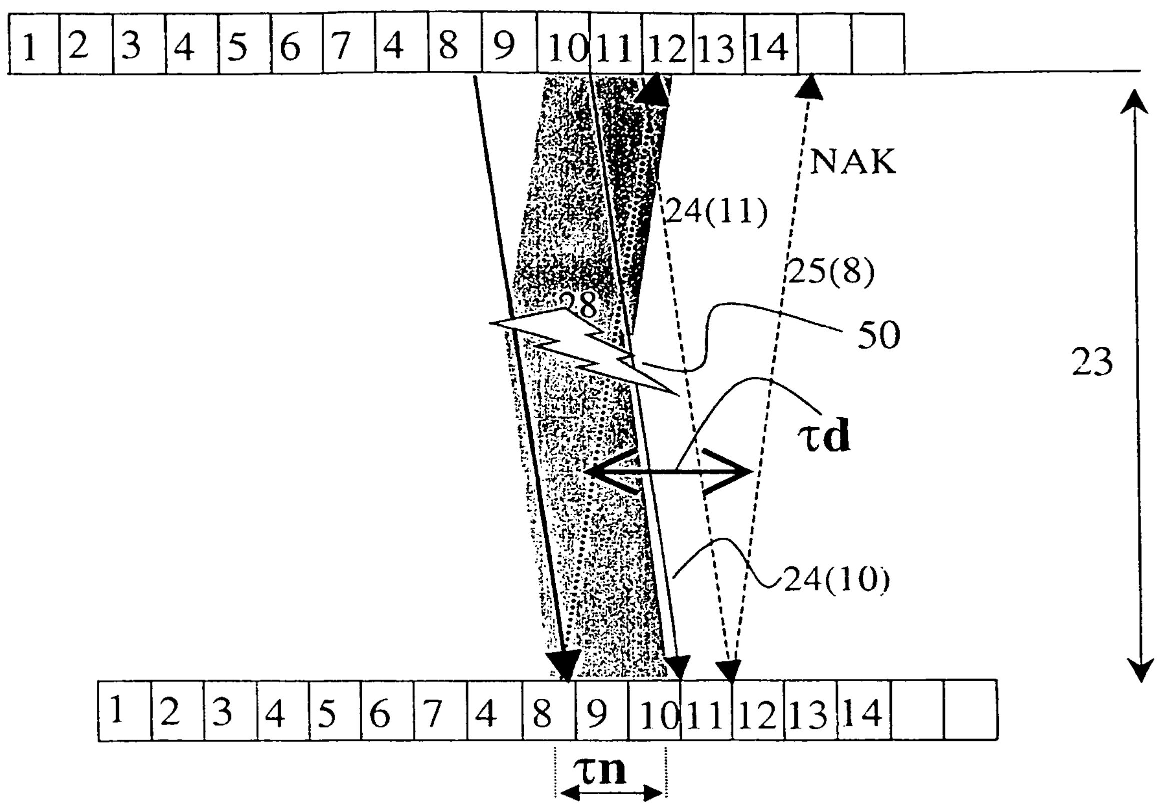
1 2 3 4 5 6 7 4 8 9 10 11 12 13 14
NAK
24(11)
25(8)
28
50
23
τd
24(10)
1 2 3 4 5 6 7 4 8 9 10 11 12 13 14
τn

FIGURE 5

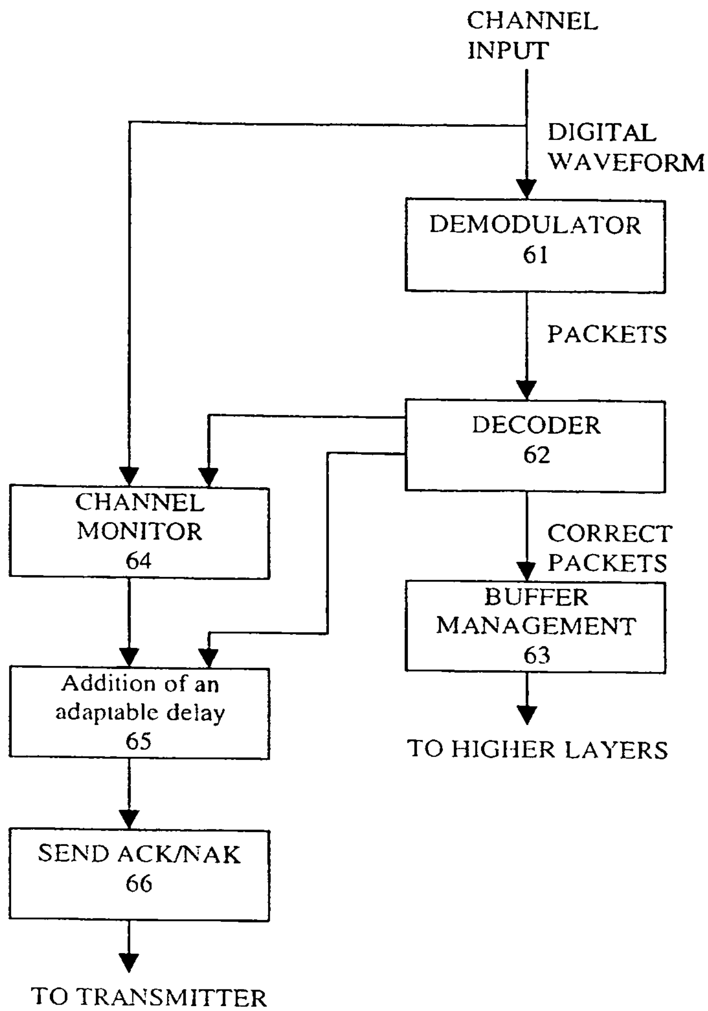
CHANNEL
INPUT
DIGITAL
WAVEFORM
DEMODULATOR
61
PACKETS
DECODER
62
CHANNEL
MONITOR
64
CORRECT
PACKETS
BUFFER
MANAGEMENT
63
Addition of an
adaptable delay
65
TO HIGHER LAYERS
SEND ACK/NAK
66
TO TRANSMITTER

FIGURE 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 40 3278

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 5 636 230 A (CRISLER KENNETH J ET AL) 3 June 1997 (1997-06-03) * abstract * * column 3, line 6 - line 19 * * column 3, line 26 - line 28 * * column 3, line 34 - line 37 * * column 4, line 22 - line 33 * * column 5, line 1 - line 12 * * column 5, line 21 - line 23 * * column 5, line 32 - line 34 * * figures 2,3 * ---	1-10	H04L1/16
A	WO 01 22645 A (NOKIA NETWORKS OY ;GROENBERG PETRI (FI); RAJALA JUSSI (FI)) 29 March 2001 (2001-03-29) * abstract * * figures 2,4 * ---	1-10	
A,D	SUNGHYUN CHOI ET AL: "A class of adaptive hybrid ARQ schemes for wireless links" IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, MAY 2001, IEEE, USA, vol. 50, no. 3, pages 777-790, XP002204910 ISSN: 0018-9545 section III-A -----	1-10	TECHNICAL FIELDS SEARCHED (Int.Cl.7) H04L

~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
THE HAGUE	8 July 2002	GHIGLIOTTI, L

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

Application Number
EP 01 40 3278

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-10

European Patent Office

LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 01 40 3278

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1-10

   Method and system for reducing interference on the feedback channel by adaptively delaying the response signals.

2. Claims: 11-14

   Method of transmission over noisy links whereby the transmitter interrupts transmission when an unfavourable noise environment is detected.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 01 40 3278

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

08-07-2002

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US 5636230	A	03-06-1997	NONE		
WO 0122645	A	29-03-2001	WO	0122645 A1	29-03-2001
			AU	6327999 A	24-04-2001
			EP	1214810 A1	19-06-2002

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82